ASSESSMENT REPORT ON

CUMENE

FOR DEVELOPING AMBIENT AIR QUALITY OBJECTIVES

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FOREWORD

Alberta Environment maintains Ambient Air Quality Objectives[1] to support air quality management in Alberta. Alberta Environment currently has ambient objectives for more than thirty substances and five related parameters. These objectives are periodically updated and new objectives are developed as required.

With the assistance of the Clean Air Strategic Alliance, a multi-stakeholder workshop was held in October 2000 to set Alberta's priorities for the next three years. Based on those recommendations and the internally identified priority items by Alberta Environment, a three-year work plan ending March 31, 2004 was developed to review four existing objectives, create three new objectives for three families of substances, and adopt six new objectives from other jurisdictions.

In order to develop a new three-year work plan, a multi-stakeholder workshop was held in October 2004. This study was commissioned in preparation for the workshop to provide background information on alternative, science based, and cost effective methods for setting priorities.

This document is one of a series of documents that presents the scientific assessment for these adopted substances.

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Project Manager
Science and Standards Branch

[1] **NOTE**: The *Environmental Protection and Enhancement Act*, Part 1, Section 14(1) refers to "ambient environmental quality objectives" and uses the term "guidelines" in Section 14(4) to refer to "procedures, practices and methods for monitoring, analysis and predictive assessment." For consistency with the *Act*, the historical term "ambient air quality guidelines" is being replaced by the term "ambient air quality objectives." This document was prepared as the change in usage was taking place. Consequently any occurrences of "air quality guideline" in an Alberta context should be read as "air quality objective."

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ACRONYMS AND ABBREVIATIONS

AAQC	Ambient Air Quality Criterion
ACGIH	American Conference of Governmental Industrial Hygienists
AENV	Alberta Environment
ATSDR	Agency for Toxic Substances and Disease Registry
CNS	Central Nervous System
ECB	European Chemicals Bureau
FTIR	Fourier Transform Infrared Spectrometry
GC/FID	Gas Chromatography/Flame Ionization Detection
HSDB	Hazardous Substances Database
ICPS	International Programme on Chemical Safety
IRIS	Integrated Risk Information System
LOAEL	Lowest Observable Adverse Effect Level
MRL	Minimum Risk Level
MOE	Ontario Ministry of the Environment
MW	Molecular Weight
NIST	National Institute of Standards and Technology
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No Observable Adverse Effect Level
NPRI	National Pollutant Release Inventory
NTP	National Toxicology Program
OECD	Organization for Economic Cooperation and Development
OEL	Occupational Exposure Limit
OSHA	Occupational Safety and Health Administration
POI	Point of Impingement
RfC	Reference Concentration
TLV	Threshold Limit Value
TWA	Time Weighted Average
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organization

SUMMARY

Cumene is a colourless, flammable, and volatile liquid with a sharp aromatic odour. Structurally similar to ethylbenzene and toluene, cumene is nearly insoluble in water but soluble in alcohol and other solvents. This substance is found in crude oil, gasoline, solvents, plants (essential oils), food, and cigarette smoke. Cumene is primarily used for the synthesis of acetone and phenol, and also used as a catalyst for acrylic polyester resins and as a solvent in the automobile and printing industries.

In the atmosphere, cumene exists as a vapour and is primarily degraded by reactions with hydroxyl radicals; it is not readily susceptible to photolysis or ozone oxidation. Cumene adsorbs strongly to soils and is unlikely to leach to groundwater. It will volatilize from dry soil surfaces or undergo aerobic biodegradation within the soil. In water, cumene will undergo volatilization from the surface or bind to sediment and undergo aerobic biodegradation. There is a potential for cumene to bioconcentrate in fish.

Plants, marsh grasses, crude petroleum and coal tar are natural sources of cumene. Cumene has also been reported to occur in a wide range of foods, including papaya, grapes, Sapodilla fruit, honey, tomatoes, dried legumes, pea seeds, cooked rice, oat groats, baked potatoes, Beaufort cheese, Zinfandel wine, fried bacon, fried chicken and pork, and curly parsley.

Anthropogenic sources of cumene emissions in Canada include crude petroleum and natural gas industries, refined petroleum and coal products industries, the chemical and chemical products industries and plastics industries. Other anthropogenic sources of emissions include leather tanning, iron and steel manufacturing, paving and roofing, paint and ink formulation, printing and publishing, ore mining, electroplating and pulp and paper production. Urban ambient air concentrations (mean values) reported for cumene in several urban air samples ranged from 0.245 $\mu g/m^3$ to 16.7 $\mu g/m^3$.

The acute and sub-acute inhalation effects of cumene in animals are largely respiratory and neurobehavioural effects. Animals could tolerate very high concentrations (sub-lethal) for short time periods, with acute symptoms subsiding following withdrawal from exposure. Limited documentation of human effects suggests the potential for acute irritation of the eyes and upper respiratory tract following exposure to cumene vapours.

No chronic animal studies (*i.e.*, exposure greater than 90 days) were identified for cumene. Sub-chronic inhalation studies on rats reported neurological effects and effects on adrenal tissue and kidney weights. Developmental effects and evidence of maternal toxicity in rats were reported at doses comparable to those reported in rats for subtle effects on adrenals and kidneys. Genotoxicity assays suggest that cumene is not genotoxic; however, there are no long-term exposure data available to determine the potential carcinogenicity of cumene.

No data were identified for the effects of cumene on terrestrial vegetation. The effects of cumene in liquid media on algae included decreased photosynthesis (*Chlorella vulgaris* and *Chlamydmonas angulosa*) and inhibited growth rate (*Selenastrum capricornutum*).

Air sampling and analytical methods for cumene are based on solid sorbent, canister or pump-and-tube sampling approaches that are followed with various analytical techniques. Reference air monitoring methods for cumene have been developed, tested, and reported by the US Environmental Protection Agency (US EPA) and U.S. occupational agencies. Alternative sampling techniques include passive gas badge samplers and a novel portable gas chromatograph for near-real time, quantitative determinations of ambient levels. There are currently no standard air sampling and analytical methods for cumene employed in either Alberta or Canada.

Ontario is the only agency in Canada to develop ambient air quality guidelines for cumene based on odour threshold and the US EPA Reference Concentration (RfC) for cumene. In the United States, acute and/or chronic exposure guidelines have been developed by the US EPA and the states of Indiana, Louisiana, Michigan, New Hampshire, Oklahoma, Texas, Washington, and Wisconsin. With the exception of the US EPA, Michigan, and New Hampshire, agencies developed ambient air quality guidelines based on occupational exposure limits (OELs).

The OELs developed by different agencies for cumene are essentially the same for 8-hour time-weighted average exposures (*i.e.*, 246 mg/m^3 and 245 mg/m^3). These OELs were then divided by a wide range of safety factors to develop 1-hour, 8-hour, 24-hour, and annual average ambient air quality guidelines. In general, the safety factors were applied to adjust for longer exposure periods and to account for sensitive individuals in the general public.

The use of OELs is cautioned in the development of ambient air quality guidelines or objectives. Occupational limits are established for a population of healthy workers (*e.g.*, 17 to 65 years) and are based on workplace information, including limited exposures (40 hours per week), daily breaks, and extended weekend periods in which the body may recover from exposure. In addition, workers sensitive to chemical exposure often leave their positions and may not be represented in clinical or epidemiological studies of chemical effects from occupational exposure.

OELs are not established for continuous exposure and are not an accurate reflection of the sensitivity of individuals who are not found in the workplace (*e.g.*, elderly and infants). It is for these reasons that agencies using occupational limits have a policy of adjusting them downward with the use of safety factors to derive ambient guidelines. As evident in the wide range of safety factors used to develop ambient air quality guidelines for cumene, uncertainty exists in terms of whether too little (or too much) safety is inherent in guidelines developed from occupational limits.

1.0 INTRODUCTION

Ambient air quality objectives are established by Alberta Environment as part of the Alberta air quality management system, Section 14 of the Environmental Protection and Enhancement Act (AENV, 2000). The purpose of this assessment report was to provide a review of scientific and technical information to assist in evaluating the basis and background for an ambient air quality objective for cumene. The following aspects were examined as part of the review:

- Physical and chemical properties;
- Existing and potential anthropogenic emissions sources in Alberta;
- Effects on humans, animals, and vegetation;
- Monitoring techniques, and;
- Ambient air guidelines and objectives in other Canadian jurisdictions, United States, World Health Organization and New Zealand, and the basis for development and use.

The physical and chemical properties identified for cumene include chemical structure, molecular weight, melting and boiling points, water solubility, density, vapor density, organic carbon partition coefficient, octanol water partition coefficient, vapor pressure, Henry's Law constant, bioconcentration factor, and odour threshold. A discussion of the behaviour of cumene in the environment was also presented.

Existing and potential natural and anthropogenic sources of cumene emissions in Alberta were examined. The chemical is currently a reportable substance on Environment Canada's National Pollutant Release Inventory.

Scientific information about the effects of cumene on humans, animals, and vegetation were identified. There were no epidemiological (human) studies on the effects of cumene inhalation in peer reviewed evaluations conducted by the European Chemicals Bureau, the World Health Organization, and the U.S. Environmental Protection Agency (US EPA). Information on the effects of cumene on vegetation was limited to two studies.

Air sampling and analytical methods for cumene used in practice by regulatory agencies were included in this assessment. Standard air monitoring methods for cumene are based on solid sorbent, canister or pump-and-tube sampling approaches that are followed with various analytical techniques. Reference air monitoring methods for cumene have been developed, tested, and reported by the US EPA, the National Institute of Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA). There are currently no standard air sampling and analytical methods for cumene employed in either Alberta or Canada.

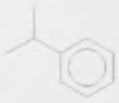
Ambient air guidelines for cumene are used by a number of jurisdictions in North America for different averaging-time periods. These guidelines were developed using an occupational exposure level and dividing it by safety or adjustment factors, using US EPA non-cancer risk assessment procedures, or based on odour thresholds. The basis for how these approaches are used by different jurisdiction to develop guidelines was investigated in this report.

2.0 GENERAL SUBSTANCE INFORMATION

Cumene is a colourless liquid with a sharp aromatic odour (Genium, 1999; WHO, 1999; ECB, 2001). This compound is flammable and volatile (ECB, 2001). Cumene reacts violently with acids and strong oxidants, forming explosive peroxides (IPCS, 2001). Cumene is soluble in alcohol and other solvents, though nearly insoluble in water (WHO, 1999). This compound is an alkyl aromatic hydrocarbon, structurally similar to ethylbenzene and methylbenzene (toluene) (WHO, 1999).

The chemical formula, structure, registry numbers, synonyms and trade names for cumene are provided in Table 1 (NIST, 2003).

Table 1 Identification of Cumene

Property	Value
Formula	$C_6H_5CH(CH_3)_2$
Structure	
CAS Registry number	98-82-8
RTECS number[1]	GR8575000
UN number	UN 1918
Synonyms	Cumol; Isopropylbenzene; 2-Phenylpropane; (1-Methylethyl)benzene; Isopropylbenzol; Benzene,isopropyl-; Cumeen; Isopropilbenzene; Isopropylbenzeen; Isopropylbenzen; Propane, 2-phenyl-; 2-Fenilpropano; 2-Fenyl-propaan.

[1] IPCS, 2001

Cumene is a naturally occurring component of crude oil (0.1 to 1%), gasoline (1%), and solvents (3%)(WHO, 1999; ECB, 2001). This compound also occurs in plants (essential oils), food and cigarette smoke (HSDB, 2004). Cumene is primarily used for the synthesis of acetone and phenol, to a lesser extent, cumene is used in the manufacture of alpha-methylstyrene, acetophenone, di-isopropyl benzene and detergents. This compound is also used as a catalyst for acrylic polyester resins and as a solvent in the automobile and printing industries (WHO, 1999; ECB, 2001).

2.1 Physical, Chemical and Biological Properties

The physical and chemical properties of cumene are summarized in Table 2.

Table 2 Physical and Chemical Properties of Cumene

Property	Value	Reference
Molecular Weight	120.19 g/mole	ECB, 2001
Physical State	Liquid	ECB, 2001
Melting Point	-96.0 °C	ECB, 2001
Boiling Point	152.7 °C	ECB, 2001
Specific gravity (liquid)	0.862	ECB, 2001
Specific gravity (gas) (air=1)	4.13	ECB, 2001
Vapour Pressure	4.5 mmHg at 25 °C	HSDB, 2004
Solubility	Soluble in organic solvents	ECB, 2001; HSDB, 2004
Solubility in water	50 mg/L at 25 °C 61.3 mg/L at 25 °C Insoluble	ECB, 2001 HSDB, 2004 Genium, 1999
Henrys Law Constant at 25 °C	1.16 atm-m^3/mol	EFDB, 2003
Octanol water partition coefficient (Log K_{ow})	3.66 3.55 at 23 °C	HSDB, 2004 ECB, 2001
Organic carbon partition coefficient (Log K_{oc})	3.45 (estimated)	Genium, 1999
Flash Point	35 °C (closed cup) 39°C (closed cup)	WHO, 1999 Genium, 1999
Explosive limits	0.9% to 6.5%	ECB, 2001
Autoignition temperature	424 °C	ECB, 2001
Odour threshold	0.43 mg/m^3 0.06 mg/m^3	WHO, 1999 Genium, 1999
Bioconcentration factor in fish (BCF)	35	HSDB, 2004
Conversion factors for vapour (at 20 °C and 101.3 kPa)	1 ppm = 5.2 mg/m^3 1 mg/m^3 = 0.19 ppm	WHO, 1999

2.2 Environmental Fate

In the atmosphere, cumene exists as a vapour and is primarily degraded by reactions with hydroxyl radicals; it is not readily susceptible to photolysis or ozone oxidation (WHO, 1999; HSDB, 2004). Cumene is unlikely to leach to groundwater as it adsorbs strongly to soils (Genium, 1999). This compound will volatilize from dry soil surfaces or undergo aerobic biodegradation within the soil (HSDB, 2004; Genium, 1999; WHO, 1999). If released to water, cumene will undergo volatilization from the surface or will bind to sediment and undergo aerobic biodegradation (HSDB, 2004; Genium, 1999). There is potential for cumene to bioconcentrate in fish based on measured and estimated BCF values (WHO, 1999; Genium, 1999; HSDB, 2004).

A summary of the environmental fate and half-lives for cumene is provided in Table 3 (HSDB, 2004).

Table 3 Environmental Fate of Cumene

System	Fate	Half life
Water	Adsorption to sediment and suspended solids, volatilization from surface.	Estimated half-life in surface water of model river and model lake due to volatilization: 1.2 hours and 4.4 days, respectively. Aerobic degredation in river water and sediment via mineralization: 34.6 days
Soil	Adsoprtion and biodegradation, some volatilization from moist soil.	
Air	Degradation via reaction with hydroxyl radicals.	Atmospheric half-life of 2.5 days due to reaction with hydroxyl radicals.

3.0 EMISSION SOURCES AND INVENTORIES

3.1 Emission Sources and Ambient Levels

Cumene is emitted to the atmosphere via both natural and anthropogenic sources. These emissions sources, as well as ambient concentration levels, are described in more detail in the following sections.

3.1.1 Natural Sources

Cumene has been identified in a number of natural substances, including plants, marsh grasses and foodstuffs (HSDB, 2004). Cumene has been detected in foodstuffs such as papaya (Flath and Forrey, cited in HSDB, 2004), Sapodilla fruit Macleaod and Gonzales de Troconis, cited in HSDB, 2004), honey (Graddon *et al.* cited in HSDB, 2004), tomatoes Schormueller and Kochmann, cited in HSDB, 2004), Concord grapes (Stern *et al.* cited in HSDB, 2004), dried legumes (Lovegren *et al.* cited in HSDB, 2004), pea seeds (Fisher *et al.* cited in HSDB, 2004), cooked rice (Yajima *et al.* cited in HSDB, 2004), oat groats (Heydanek and McGorrin, cited in HSDB, 2004), baked potatoes (Coleman *et al.* cited in HSDB, 2004), Beaufort cheese (Dumaont and Adda, cited in HSDB, 2004), Zinfandel wine (Stern *et al.* cited in HSDB, 2004), fried bacon (Ho *et al.* cited in HSDB, 2004), fried chicken and pork (Shahidi *et al.* cited in HSDB, 2004). It has also been identified in curly parsley (Vernon and Richard, cited in HSDB, 2004) and oakmoss (Gavin *et al.* cited in HSDB, 2004; Tabacchi and Nicollier, cited in HSDB, 2004). Cumene also occurs in crude petroleum and coal tar (RSC, 1999; WHO, 1999).

3.1.2 Anthropogenic Sources

Anthropogenic sources of cumene to the atmosphere are largely the result of emissions from manufacturing and processing plants, and emissions during its transport (HSDB, 2004). As cumene occurs in crude oil and fuels, the transport, distribution and incomplete combustion of these fuels also lead to releases of cumene (HSDB, 2004). It was estimated that the releases of cumene as a result of the above-mentioned sources represented 21 million pounds annually (Jackson *et al.* cited in HSDB, 2004).

Other anthropogenic sources of cumene include leather tanning, iron and steel manufacturing, paving and roofing, paint and ink formulation, printing and publishing, ore mining, coal mining, organics and plastics manufacturing, pesticide manufacturing, electroplating and pulp and paper production (Shakelford *et al.* cited in HSDB, 2004). Cumene may also be released from the vulcanization of rubber (Cocheo *et al.* cited in HSDB, 2004), building materials (Moelhave, cited in HSDB, 2004), jet engine exhaust (Katzman and Libby, cited in HSDB, 2004), outboard motor operation (Montz *et al.* cited in HSDB, 2004), solvent use (Levy, cited in HSDB, 2004), pharmaceutical production (Brown *et al.* HSDB, 2004), textile plants (Gordon and Gordon, cited in HSDB, 2004) and cigarette tobacco (WHO, 1999).

According to the National Pollutant Release Inventory (NPRI), the industrial sectors contributing to cumene emissions are the crude petroleum and natural gas industries, refined petroleum and coal products industries, the chemical and chemical products industries and the plastic products industries (NPRI, 2004). Table 4 provides the total emissions of cumene as reported in the 2001

NPRI database (NPRI, 2004). Table 5 presents the air emissions of cumene as reported in the 2001 NPRI database (NPRI, 2004).

3.1.3 Ambient Levels

Ambient air concentrations for cumene in urban and remote settings are described in HSDB (2004) and Spicer *et al.* (2002). Cumene was detected in several urban air samples with mean concentrations ranging from 0.245 $\mu g/m^3$ to 16.7 $\mu g/m^3$ (HSDB, 2004). Cumene was also detected in ambient air samples taken from a remote area however it is believed that the cumene detected in these samples may have been influenced by urban areas (Helmig and Arey, cited in HSDB, 2004).

Table 4 Total Emissions of Cumene According to the 2001 NPRI Database (NPRI, 2004)

NPRI ID	Company	City	Province	Emissions of Cumene (tonnes)				
				Air	Water	Land	Underground	Total
2274	Syncrude Canada Ltd.	Fort McMurray	AB	10.932	0	0	0	10.932
3707	Imperial Oil	Edmonton	AB	0.380	0	0	0.069	0.449
2960	Shell Canada Products	Fort Saskatchewan	AB	0.001	0	0	0	0.001
5351	Baker Petrolite Corporation	Calgary	AB	0	0	0	0	0.002
2776	Chevron Canada Limited	Burnaby	BC	0.045	0	0	0	0.045
4101	Irving Oil Limited	Saint John	NB	0.059	0	0	0	0.059
3071	Sunoco Inc.	Sarnia	ON	1.410	0	0	0	1.41
3704	Imperial Oil.	Sarnia	ON	0.589	0	0	0	0.589
3701	Imperial Oil Limited	Nanticoke	ON	0.223	0	0	0	0.223
7002	Canadian Polystyrene Recycling Association	Mississauga	ON	0.178	0	0	0	0.178
1464	Imperial Oil.	Sarnia	ON	0.118	0	0	0	0.118
3146	Dow Chemical Canada Inc.	Sarnia	ON	0.006	0	0	0	0.006
5897	Durham Furniture Inc.	Durham	ON	0	0	0	0	0.003
3962	Shell Canada Products	Corunna	ON	0	0	0	0	0.005
4849	Tarxien Components Corporation	Concord	ON	0	0	0	0	0.302
1492	ATOFINA Canada Inc.	Bécancour	QC	0.857	0	0	0	0.857
3897	Petro-Canada	Montreal	QC	0.276	0	0.001	0	0.277
3127	Produits Shell Canada	Montreal-est	QC	0.220	0	0.050	0	0.27
4048	Consumers' Co-operative Refineries Ltd./NewGrade Energy Inc.	Regina	SK	0.116	0	0.003	0	0.119

Table 5 Air Emissions of Cumene According to the 2001 NPRI Database (NPRI, 2004)

NPRI ID	Company	City	Province	Air Emissions of Cumene (tonnes)					
				Stack /Point	Storage /Handling	Fugitive	Spills	Other Non-Point	Total
2274	Syncrude Canada Ltd.	Fort McMurray	AB	0.033	0.332	10.567	0	0	10.932
3707	Imperial Oil	Edmonton	AB	0	0.260	0.117	0	0.003	0.380
2960	Shell Canada Products	Fort Saskatchewan	AB	0	0.001	0	0	0	0.001
5351	Baker Petrolite Corporation	Calgary	AB	0	0	0	0	0	0
2776	Chevron Canada Limited	Burnaby	BC	0	0.031	0.014	0	0	0.045
4101	Irving Oil Limited	Saint John	NB	0	0	0.059	0	0	0.059
3071	Sunoco Inc.	Sarnia	ON	0	0.176	1.234	0	0	1.410
3704	Imperial Oil.	Sarnia	ON	0	0.015	0.574	0	0	0.589
3701	Imperial Oil Limited	Nanticoke	ON	0	0.060	0.162	0	0.001	0.223
7002	Canadian Polystyrene Recycling Association	Mississauga	ON	0.178	0	0	0	0	0.178
1464	Imperial Oil.	Sarnia	ON	0	0	0.118	0	0	0.118
3146	Dow Chemical Canada Inc.	Sarnia	ON	0	0	0	0	0.006	0.006
5897	Durham Furniture Inc.	Durham	ON	0	0	0	0	0	0
3962	Shell Canada Products	Corunna	ON	0	0	0	0	0	0
4849	Tarxien Components Corporation	Concord	ON	0	0	0	0	0	0
1492	ATOFINA Canada Inc.	Bécancour	QC	0.564	0.001	0.292	0	0	0.857
3897	Petro-Canada	Montreal	QC	0.101	0.005	0.170	0	0	0.276
3127	Produits Shell Canada	Montreal-est	QC	0	0.170	0.050	0	0	0.220
4048	Consumers' Co-operative Refineries Ltd./NewGrade Energy Inc.	Regina	SK	0	0.069	0.019	0.001	0.027	0.116

4.0 EFFECTS ON HUMANS, ANIMALS AND VEGETATION

The following is a summary of the available toxicological and epidemiological studies on the health effects of cumene following inhalation. Effects following oral and dermal exposure were not reviewed in detail. The primary literature sources were taken from international peer-reviewed assessments of the health effects of cumene by the European Chemicals Bureau (ECB, 2001), the World Health Organization (WHO, 1999), and the U.S. Environmental Protection Agency (US EPA, 1997).

Exposure-response data from key toxicological studies were summarized in table form to provide a quick reference to health effects observed in critical receptors over a defined period of inhalation exposure to cumene. The relevance of this data to public health was then discussed.

4.1 Overview of Chemical Disposition

Cumene was rapidly absorbed, metabolized, and excreted by Fischer F-344 rats exposed via inhalation to a single nose-only dose of 100, 500, or 1500 ppm (Research Triangle Institute, cited in ECB, 2001). Cumene was detected in the blood within 5 minutes of exposure and was distributed to adipose tissue, liver, and kidneys. Over 70% of the absorbed dose was excreted in the urine. Elimination via expired breath and faeces occurred to a smaller extent (more evident at higher doses). The major metabolite produced was 2-phenyl-2-propanol and its glucuronide or sulphate conjugates (50% or more); other metabolites identified were 2-phenyl-1,2-propanediol and 2-phenylproprionic acid. Similar urinary metabolites were reported in rabbits exposed to cumene by gavage and following *in vitro* exposure of rabbit liver soluble enzyme fraction (Robinson *et al.* Chakraborty and Smith, cited in ECB, 2001). Cumene was detected in endocrine organs, central nervous system, bone marrow, spleen, and liver of rats exposed via inhalation to cumene vapour for up to 150 days (Fabre *et al.* cited in WHO, 1999).

In several human exposure studies, cumene was reported to be associated with human metabolism as it was detected in the breath of non-smoking (urban) men and women having no occupational exposure to the chemical (Conkle *et al.* Krotoszynski *et al.* cited in ECB, 2001).

Cumene was detected in the urine, blood, and alveolar air of individuals exposed to mean air concentrations of 6 µg cumene/m^3 (Parbellini *et al.* cited in ECB, 2001). Ten healthy male and female human volunteers were exposed under controlled conditions to cumene vapour concentrations of 249, 480 or 720 mg/m^3 (49, 98, 147 ppm) for 8 hour periods every 10 days (Senczuk and Litewka, cited in WHO, 1999 and US EPA, 1997). The mean respiratory tract absorption of cumene was 50% (ranging from 45 to 64%), with males absorbing nearly twice as much as females. Cumene excretion was measured by levels of 2-phenyl-2-propanol in the urine. Maximum excretion occurred after 6 to 8 hours of exposure and dropped off to near zero 40 hours post exposure. It was estimated that 35% of the absorbed dose was excreted in the urine as 2-phenyl-2-propanol. In a study of alveolar and blood cumene concentrations, Brugnone *et al.* (cited in ECB, 2001) reported alveolar cumene retention from 70.4 % in hospital staff to 77.8% in chemical workers (benzene manufacturing) exposed to mean air concentrations of 6.4 µg cumene/m^3 and 10.7 µg cumene /m^3, respectively.

4.2 Genotoxicity

Numerous *in vitro* and *in vivo* assays for genotoxicity have been conducted using cumene in various test systems (ECB, 2001; WHO, 1999; US EPA, 1997). With one exception, all of the assays were negative for genotoxicity.

Results were negative for *in vitro* Ames tests in *Salmonella Typhimurium* (TA98, TA100, TA1535, and TA1537) conducted with and without metabolic activation (Lawlor and Wagner, Florin *et al.* cited in ECB, 2001; WHO, 1999, and; U.S. EPA, 1997). *In vitro* studies on DNA damage were also negative for cell transformation in BALB/3T3 mouse embryo cells without metabolic activation (Putnam, cited in ECB, 2001 and U.S. EPA, 1997), gene mutations or chromosomal aberrations in Chinese hamster ovary cells with and without metabolic activation (Yang, Putnam, cited in ECB, 2001; WHO, 1999, and; U.S. EPA, 1997), and, unscheduled DNA synthesis in primary rat hepatocytes (Curren, cited in ECB, 2001; WHO, 1999, and; U.S. EPA, 1997).

Mixed results were reported in micronucleus assays conducted following *in vivo* exposure of mice (Gulf Oil Corporation, cited in ECB, 2001; WHO, 1999 and U.S. EPA, 1997) and rats (NTP, cited in WHO, 1999 and U.S. EPA, 1997) to cumene. The Gulf Oil Corporation reported that cumene was not clastogenic following *in vivo* exposure of mice to cumene at 250, 500, or 1000 mg/kg body weight/day for 2 days. The study conducted by the NTP reported weakly positive results (without evidence of dose-response) for rats exposed by a single intraperitoneal injection to up 2,500 mg cumene/kg body weight. It should be noted that the highest dose used in this study resulted in 50% death of the test animals (U.S. EPA, 1997).

4.3 Acute and Sub-Acute Effects

Acute effects usually occur rapidly as a result of short-term exposures and are of short duration – generally for exposures less than 24 hours. Sub-acute effects usually occur as a result of exposures that are of an intermediate duration – generally for exposures lasting a few days to no greater than one month (Eaton and Klaasson, 1996).

4.3.1 Acute and Sub-Acute Human Effects

No studies on the effects of cumene in humans following acute or sub-acute exposures were identified.

4.3.2 Acute and Sub-Acute Animal Effects

Table 6 lists the No-Observable-Adverse-Effect-Levels (NOAELs) and Lowest-Observable-Adverse-Effect Levels (LOAELs) reported in the literature from acute and sub-acute exposures of animals to cumene. Further discussion of these effects is provided following the table.

Table 6 Effects of Acute and Sub-Acute Cumene Inhalation (Experimental Animals)

Effects Reported	Air Concentration [a] ppm (mg/m^3)	Exposure Period	Species	Reference
Death (LC_{50}):	25000 (121,000)	2 hours	Mice	Izmerov *et al.* cited in ECB, 2001
	8000 (40,000)	4 hours	Rat	Smyth *et al.* cited in ; ECB, 2001; WHO, 1999
	2000 (10,000)	7 hours	Mice	Werner *et al*; Dow Chemical Company, cited in ECB, 2001
Systemic:				
Respiratory tract irritation: RD_{50} (50% reduction in respiratory rate)	2,058 (10,084)	30 min	Mice	Kristiansen *et al.* cited in ECB, 2001; WHO, 1999.
	2,900 (14,255)	Not specified	Mice	Nielsen and Alarie, cited in ECB, 2001.
NOAEL Depressed respiratory frequency	580 (2,850)	6 hours	Rat	Research Triangle Institute, cited in ECB, 2001.
LOAEL Laboured respiration	2,000 (9,800)	6 h/d, 5 d	Rat Fischer 344	Gulf Oil Corporation, cited in WHO, 1999; ECB, 2001
Neurological:				
NOAEL CNS Depression (behavioural function)	100 (490)	6 hours	Rat	Bushy Run Research Centre, cited in ECB, 2001.
NOAEL CNS Depression (behavioural function)	100 (490)	6 hours	Rat Fischer 344	Cushman *et al.* cited in WHO, 1999
LOAEL CNS Perturbations (behavioural function)	2000 (9,800)	6 h/d, 5 d	Rat Fischer 344	Gulf Oil Corporation, cited in WHO, 1999; ECB, 2001
NOAEL CNS Perturbations (behavioural function)	251 (1,230)	6 h/d, 5 d/wk, 2 wks	Rat Fischer 344	Chemical Manufacturers Association, cited in WHO, 1999
LOAEL CNS Perturbations (behavioural function)	105 (515)	6 h/d, 5 d/wk, 4 wks	Rat Sprague-Dawley	Monsanto Co, cited in WHO, 1999.

[a] When both units of concentration were not provided in the literature, the following conversion factor and assumptions were used: mg/m^3 x 24.45/MW =ppm; MW=130.23, air at 25°C and 101.3 kPa (760mmHg) (Plog *et al.* 1996).

4.3.2.1 Respiratory Effects

Two studies reported RD_{50} values (a 50% decrease in respiratory rate) of 10,084 mg/m^3 and 14,255 mg/m^3 for mice exposed via inhalation to cumene (Kristiansen, *et al.* cited in ECB, 2001; WHO, 1999 and Nielsen Alarie, cited in ECB, 2001). These effects occurred at lethal air concentrations (LC_{50} of 10,000 mg/m^3) for mice exposed for 7 hours to cumene (Werner *et al*; Dow Chemical Company, cited in ECB, 2001). Respiratory paralysis is one of the causes of death reported in animals acutely exposed via inhalation to cumene (also pulmonary edema and hemorrhaging) (Gerarde, Werner *et al.* Dow Chemical Company, cited in ECB, 2001).

Groups of 3 male and 3 female rats were exposed via inhalation to a single dose of 0, 2,850 mg/m^3, or 7,275 mg/m^3 cumene (Research Triangle Institute, cited in ECB, 2001). A significant decrease in respiratory frequency as well as severe motor impairment and narcosis was observed in rats exposed to 7,275 mg/m^3 cumene, however, no respiratory effects were observed at 2,850 mg/m^3.

4.3.2.2 Neurological Effects

Groups of 10 rats were exposed (nose-only) for 6 hours to a dose of cumene vapour at concentrations of 0, 490, 2,450 or 5,880 mg/m^3 (Bushy Run Research Centre, 1989, cited in ECB, 2001). Acute behavioural effects (*i.e.*, gait abnormalities, decreased rectal temperature, and increased activity) were observed 1 hour after exposure in the two highest dose groups, but subsided within 6 or 24 hours following exposure.

Groups of Fischer-344 rats were exposed (whole body) for 6 hours to a single dose of 0, 490, 2,430, or 5,980 mg cumene/m^3 (Cushman *et al.* cited in WHO, 1999). Gait abnormalities, decreased rectal temperature, and decreased activity were reported 1 hour post-exposure for rats exposed to the highest dose only. Decreased activities also occurred in females exposed to 2,430 mg cumene/m^3. A decreased response to toe pinch was reported six hours post-exposure, but only in males from the highest dose group.

Acute neurobehavioural effects (including changes in posture, gait, mobility, strength and psychomotor coordination) were also reported in mice exposed by whole body inhalation for 20 minutes to single high concentrations of cumene (9,800 mg/m^3, 19,600 mg/m^3, and 39,200 mg/m^3) (Tegeris and Balster, cited in WHO, 1999; ECB, 2001). Recovery was reported within minutes of removal from exposure.

Male and female Sprague-Dawley rats exposed (whole body) to cumene vapour concentrations of 0, 515, 1,470 or 2,935 mg/m^3 for 6 hours/day, 5 days/week, over a 4 week period were observed for neurobehavioural effects (*i.e.*, side to side head movements, head tilt and arched back) (Monsanto Co, cited in WHO, 1999). Dose-related increases in side-to-side head movements and head tilt were reported for all groups.

Groups of 15 male and 15 female Fischer 344 rats exposed (whole body) to 0, 9,800 or 24,500 mg/m^3 cumene vapour for 6 hours a day were observed over a 5 day exposure period (Gulf Oil Corporation, cited in WHO, 1999; ECB, 2001). All rats in the highest exposure dose group died within 2 days. At the low dose, central nervous system effects observed in exposed animals included hypothermia, staggering, laboured respiration, and lethargy).

Another study on Fischer 344 rats exposed (whole body) groups of 10 male and 10 female to 0, 1,230, 2,680, 5,130, or 6,321 mg/m^3 cumene vapour for 6 hours a day, 5 days a week over a two week period (Chemical Manufacturers Association, cited in WHO, 1999). Neurological effects (decreased motor activity or hyperactivity, ataxia) occurred in all but the lowest dose group.

4.4 Sub-Chronic and Chronic Effects

Sub-chronic effects generally occur following one to three months of exposure, while chronic effects occur as a result of repeated exposures for a period greater than 3 months (Eaton and Klaassen, 1996).

4.4.1 Chronic Human Effects

No recent studies on the chronic or sub-chronic exposure of humans to cumene were identified (EPA, 1997; WHO, 1999). However, in 1948 the Dow Chemical Company reported "no toxic injury" from daily exposure over 1-2 years to "readily tolerated" cumene concentrations; presumably below 400 ppm (1,966 mg/m^3) as most persons exposed to higher concentrations experienced eye and upper respiratory tract irritation (Dow Chemical Company, cited in ECB, 2001).

4.4.2 Sub-Chronic and Chronic Animal Effects

Table 7 lists the NOAELs and LOAELs reported in the literature from sub-chronic and chronic exposures of animals to cumene. Further discussion of these effects is provided following the table.

Table 7 Effects of Sub-Chronic Cumene Inhalation (Experimental Animals)

Effects Reported	Air Concentration [a] ppm (mg/m^3)	Exposure Period	Species	Reference
Systemic:				
NOAEL Body weight, haematology, Clinical chemistry, histopathology	4 (18)	90 days continuous	Rat, guinea pig, dog, monkey	Jenkins *et al.* cited in US EPA, 1997; WHO, 1999; ECB, 2001.
NOAEL Respiratory tract tissue, lung weights	1202 (5,890)	6 h/d 5d/wk 13 weeks	Rat Fischer 344	Cushman *et al.* cited in US EPA, 1997, WHO, 1999, ECB, 2001.
Neurological:				
LOAEL	496 (2,430)	6 h/d	Rat	Cushman *et al.* cited in WHO, 1999, ECB, 2001.
NOAEL	100 (490)	5d/wk	Fischer 344	
Motor activity and systemic effects		13 weeks		
LOAEL	1,202 (5,909)	6 h/d	Rat	Cushman *et al.* cited in US EPA, 1997.
NOAEL	496 (2,438)	5d/wk	Fischer 344	
Motor activity and systemic effects		13 weeks		
Reproductive/Developmental:				
NOAEL	1202 (5,890)	6 h/d 5d/wk 13 weeks	Rat Fischer 344	Cushman *et al.* cited in WHO, 1999.
NOAEL	1,211 (5,934)	6 h/d	Rat	Darmer *et al.* cited in WHO, 1999
Developmental effects		Days 6-15	Sprague-Dawley	
NOAEL	99 (485)	of gestation		
Maternal effects				
NOAEL	1,206 (5,909)	6 h/d	Rabbit	Darmer *et al.* cited in WHO, 1999
Developmental and maternal effects		Days 6-18		
		of gestation		

[a] When both units of concentration were not provided in the literature, the following conversion factor and assumptions were used: mg/m^3 x 24.45/MW =ppm; MW=130.23, air at 25°C and 101.3 kPa (760mmHg) (Plog *et al.* 1996).

4.4.2.1 Respiratory Effects

Two sub chronic inhalation studies were performed on Fischer-344 rats (Cushman *et al.* cited in US EPA, 1997; WHO, 1999). In the first study, male and female rats (22/sex) were exposed via whole body inhalation to cumene vapours at 0, 490, 2430, or 5890 mg/m^3 for 6 hrs/d, 5 d/week for 13 weeks. In the second study, fewer rats (15/sex) were exposed and a low-dose group (245 mg/m^3) was added. The exposed rats were evaluated for neurological function, clinical signs of toxicity, body weight, food and water consumption, hematology and serum chemistry, organ weights, auditory brain stem responses, ophthalmology, sperm count and morphology, gross pathology and histopathology (including respiratory tract tissue). No significant effects on respiratory tract tissue or lung weights were reported in either study (US EPA, 1997).

4.4.2.2 Neurological and Systemic Effects

In the first of the two sub chronic inhalation studies performed on groups of male and female Fischer-344 rats (Cushman *et al.* cited in US EPA, 1997; WHO, 1999; ECB, 2001), a statistically significant exposure-related decrease in motor activity was reported for male rats exposed to the two highest doses (2,430 mg/m^3 and 5,890 mg/m^3) for 6 hours a day, 5 days a week for 13 weeks. These results were not reproduced in the second study; however, various other effects were also reported in the rats exposed to 2,430 mg/m^3, including increased water consumption, effects on haematological and serum parameters, and sporadic weight increases in adrenals (males) and kidneys (females) and clinical effects (WHO, 1999; ECB, 2001).

Alterations in relative and absolute weights of adrenals (both sexes) and kidneys (females) were statistically and biologically significant at 5,890 mg cumene/m^3 (Cushman *et al.* cited in US EPA, 1997). The US EPA (1997) viewed the effects occurring at 2,430 mg/m^3 as not biologically and statistically significant, defining this exposure dose as the NOAEL and the highest exposure dose (5,890 mg/m^3) as the LOAEL for sub-chronic cumene inhalation exposure. This NOAEL of 2,430 mg/m^3 was used by the US EPA (1997) to develop a Reference Concentration (RfC) of 400 µg/m^3 for chronic inhalation exposure to cumene.

The WHO (1999) and ECB (2001) reviewed the results of the study by Cushman *et al.* and conclude that the effects occurring at 2,430 mg/m^3 in the first study could be potentially adverse indications of the more significant effects which occurred at the next highest exposure dose, resulting in their recommendation of a LOAEL of 2,430 mg/m^3 and a NOAEL of 490 mg/m^3 for sub-chronic exposure to cumene.

4.4.2.3 Reproductive and Developmental Effects

An inhalation study was conducted in female Sprague-Dawley rats exposed (whole body) to 0, 485, 2,391 or 5,934 mg cumene/m^3 for 6 hours/day on days 6 through 15 of gestation (Darmer *et al.* cited in WHO, 1999). No significant adverse effects on reproductive parameters or fetal development were reported, resulting in the recommendation of a developmental NOAEL of 5,934 mg/m^3 for cumene inhalation (WHO, 1999). Maternal toxicity (hypoactivity, blepharospasm, and decreased food consumption) was significant at 2,391 mg/m^3, resulting in a maternal NOAEL of 485 mg/m^3 (WHO, 1999).

It should be noted that the LOAEL (2,391 mg/m^3) and NOAEL (485 mg/m^3) determined for maternal toxicity in rats are very similar to the LOAEL (2,430 mg/m^3) and NOAEL (490 mg/m^3) identified above by WHO (1999) and ECB (2001) for neurological and systemic effects in rats.

The same authors conducted an inhalation study on New Zealand White rabbits exposed (whole body) to 0, 2,418, 5,928, or 11,292 mg cumene/m^3 for 6 hours/day on days 6 through 18 of gestation (Bushy Run Research Center, cited in US EPA, 1997 or Darmer *et al.* cited in WHO, 1999). The highest exposure dose resulted in maternal mortality (2 deaths) and one abortion as well as significant reductions in body weight and food consumption, clinical signs of toxicity, lung colouration, and increased liver weights. Gestation parameters affected at this dose (concurrent with maternal toxicity although not significant) included increased nonviable implants, early resorptions, and decrease in the percent of live fetuses. The highest dose

(11,292 mg/m^3) was considered a LOAEL and the next highest dose (5,928 mg/m^3) was considered a NOAEL for maternal and developmental effects (US EPA, 1997; WHO, 1999).

No reproductive effects were reported in either male (sperm count and morphology) or female (weight changes or histopathology of reproductive organs) Fischer-344 rats exposed in the first of two sub chronic inhalation studies to cumene vapours at 0, 490, 2430, or 5890 mg/m^3 for 6 hours a day, 5 days a week for 13 weeks (Cushman *et al.* cited in US EPA, 1997; WHO, 1999).

4.4.2.4 Other Effects

No significant adverse effects were reported in several species of mammals (rats, guinea pig, dog, and monkey) following continuous exposure for 90 days to cumene vapours at concentrations of 0, 18, or 147 mg/m^3 (Jenkins *et al.* cited in US EPA, 1997; WHO, 1999; ECB, 2001). Parameters analysed included body weight, haematology, clinical chemistry and histopathology.

4.5 Summary of Adverse Health Effects of Cumene Inhalation

The weight of evidence from numerous genotoxicity assays (following *in vivo* and *in vitro* exposure to cumene) suggests that cumene is not genotoxic. There was no long-term exposure data available to determine the potential carcinogenicity of cumene.

Acute inhalation studies using lethal exposure doses (7,000 to 10,000 mg cumene/m^3) reported respiratory effects in mice and rats, including 50% decrease in respiratory rate, severe motor impairment, and narcosis. No respiratory effects were reported in rats exposed for 6 hours to cumene vapours at 2,850 mg/m^3.

Acute neurobehavioural effects were reported in rats acutely exposed for 6 hours to cumene at air concentrations ranging from 2,430 to 5,980 mg/m^3 and in mice exposed for 20 minutes to cumene concentrations ranging from 9,800 to 39,200 mg/m^3. In all cases, symptoms subsided following withdrawal from exposure; recovery was quicker in animals exposed to lower air concentrations of cumene or exposed for short time periods (*i.e.*, 20 minutes).

Neurobehavioural effects were reported in rats sub-acutely exposed to cumene vapour concentrations of 9,800 mg cumene/m^3 (6 hours/day, 5 days), 2,680 to 6,321 mg cumene/m^3 (6 hours a day, 5 days/week, 2 weeks), and from 515 to 2,935 mg cumene/m^3 (6 hours/day, 5 days/week, 4 weeks).

The only documentation of human effects following inhalation exposure to cumene (a 1948 report by the Dow Chemical Company) reported "no toxic injury" from daily exposure over 1-2 years to cumene concentrations presumably (depending on individual sensitivity) below 1,966 mg/m^3. Exposure to concentrations >1,966 mg/m^3 typically (depending on individual sensitivity) resulted in acute irritation of the eyes and upper respiratory tract.

In sub-chronic inhalation studies on rats (6 hours/day, 5 days/week, 13 weeks) a NOAEL of 5,890 mg/m^3 was reported for effects on respiratory tract tissue, lung weights, and reproductive parameters. This same dose (5,890 mg/m^3) was the LOAEL for significant alterations in adrenal

tissue and kidney weights. A LOAEL of 2,430 mg/m^3 was reported for decreased motor activity, increased water consumption, effects on haematological and serum parameters, and sporadic weight increases in adrenals and kidneys. The NOAEL for these effects was 490 mg/m^3.

In several species of mammals (rats, guinea pig, dog, and monkey), no adverse effects were reported following continuous exposure for 90 days to cumene vapours of 18, or 147 mg/m^3.

Studies in female rats exposed via inhalation to cumene vapours for 6 hours/day on days 6 through 15 of gestation, reported a developmental NOAEL of 5,934 mg/m^3, a maternal LOAEL of 2,391 mg/m^3 and a maternal NOAEL of 485 mg/m^3. This LOAEL and NOAEL are comparable to the LOAEL (2,430 mg/m^3) and NOAEL (490 mg/m^3) reported for neurological and systemic effects in rats.

In female rabbits, a NOAEL of 5,909 mg/m^3 was reported for maternal and developmental effects following exposure to cumene vapours for 6 hours/day on days 6 through 18 of gestation.

4.6 Effects on Vegetation

Little is known about the direct effects of volatile organic compounds (VOCs) on plants. A search of ecological databases (*i.e.,* Web of Science, Biological Abstracts, Toxnet (available at http://toxnet.nlm.nih.gov/), and Ecotox (available at http://www.epa.gov/ecotox/)) was conducted for literature describing the effects of cumene on terrestrial and aquatic vegetation. The search resulted in the identification of only two research article on the effect of cumene in liquid media on algae, whereas nothing has been reported on effects on terrestrial vegetation.

Hutchinson *et al.* (1980) evaluated the effect of a number of different compounds on the photosynthesis of the algal species *Chlorella vulgaris* (strain 260, Indiana Culture Collection) and *Chlamydmonas angulosa* (strain 680, Indiana Culture Collection). Photosynthesis activity was calculated as a function of $^{14}CO_2$ uptake. Both strains were grown in Bolds Basal Media (pH 6.5) at 19°C, in axenic conditions, with a light intensity of 400 foot candles. Cumene treatments were at 0, 20, 50, and 100 percent saturation level in Bolds Basal Media. The algal cultures were grown to exponential phase for all experiments. Cell concentrations for treatments were at 5 x 10^4 and 20 x 10^4 for *Chlamydomonas angulosa* and *Chlorella vulgaris*, respectively. It was reported that a 50% decrease of photosynthesis was observed with a cumene treatment (3h exposure) of 73 mmol/m^3 for *Chlamydomonas angulosa* and 177 mmol/m^3 for *Chlorella vulgaris*. Galassi *et al.* (1988) evaluated the effect of cumene on the alga *Selenastrum capricornutum*. Cumene treatment of 2.6 mg dm^3 (EC_{50}) for 72h treatment inhibited 50% exponential growth rate of the algae cultures. Algal growth rate was evaluated by Coulter counter apparatus.

5.0 AIR SAMPLING AND ANALYTICAL METHODS

5.1 Reference Methods

Air sampling and analytical methods for cumene used in practice by established agencies are reported. In general, standard air monitoring methods for cumene are based on solid sorbent, canister or pump-and-tube sampling approaches that are followed with various analytical techniques. Widely employed and accepted reference air monitoring methods for cumene have been developed, tested and reported by the United States Environmental Protection Agency (US EPA), National Institute of Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA). There are currently no standard air sampling and analytical methods for cumene employed in either Alberta or Canada. Refer to Table 8 for a description of individual method advantages and disadvantages.

5.1.1 US EPA Compendium Method TO-1

US EPA has developed a number of methodologies suitable for sampling ambient air for trace-level concentrations of cumene. US EPA Compendium Method TO-1 describes a generalized protocol for the collection and determination of certain volatile organic compounds (VOCs) (including cumene) in ambient air using Tenax solid sorbent sampling and analysis with thermal desorption and gas chromatography/mass spectrometry (GC/MS) techniques (US EPA, 1999). Advantages of this method include: good database, large volume of air can be sampled, water vapour is not collected, wide variety of compounds collected, low detection limits (i.e., 0.01-100 ppbv), standard procedures available, and practical for field use. Disadvantages of this method include: highly volatile compounds and certain polar compounds are not collected, rigorous clean-up of absorbent required, no possibility of multiple analysis, low breakthrough volumes for some compounds, structural isomers are the most common interferences, contamination of absorbent and blank contaminants may be a problem, and artifact formation.

In this method, ambient air is drawn through a cartridge containing 1 to 2 g of Tenax at a rate of 10 to 500 mL/min. Certain volatile organic compounds are trapped on the resin while highly volatile organic compounds and most inorganic atmospheric constituents pass through the cartridge. The cartridge is then transferred to the laboratory and analyzed. For analysis the cartridge is placed in a heated chamber and purged with an inert gas. The inert gas transfers the volatile organic compounds from the cartridge onto a cold trap and subsequently onto the front of the GC column that is held at low temperature (e.g., - 70°C). The GC column temperature is then increased (temperature programmed) and the components eluting from the column are identified and quantified by mass spectrometry. Component identification is normally accomplished, using a library search routine, on the basis of the GC retention time and mass spectral characteristics. Less sophisticated detectors (e.g., electron capture or flame ionization) may be used for certain applications but their suitability for a given application must be verified by the user.

5.1.2 US EPA Compendium Method TO-15A

US EPA Compendium Method TO-15A describes the determination of VOCs (including cumene) in air collected in specially prepared canisters and analyzed by GC/MS (US EPA, 1999). The advantages of this method include: incorporates a multisorbent/dry purge technique

or equivalent for water management thereby addressing a more extensive set of compounds, establishes method performance criteria for acceptance of data, provides enhanced provisions for quality control, and unique water management approach allows analysis for polar VOCs. Disadvantages of this method are it requires expensive analytical equipment and a high level of operator skill to perform.

In this method, the ambient atmosphere is sampled by introduction of 6 L of air into a specially prepared stainless steel canister (SUMMA or equivalent) over an appropriate time and rate. Both sub atmospheric pressure and pressurized sampling modes make use of an initially evacuated canister. A pump ventilated sampling line is used during sample collection with most commercially available samplers. Pressurized sampling requires an additional pump to provide positive pressure to the sample canister. A sample of air is drawn through a sampling train comprised of components that regulate the rate and duration of sampling into the pre-evacuated and passivated canister. After the air is collected the canister valve is closed, an identification tag is attached to the canister, and the canister is transported to the laboratory for analysis. Upon receipt at the laboratory the canister tag data is recorded and the canister is stored until analysis.

To analyze the sample a known volume of sample is directed from the canister through a solid multisorbent concentrator. A portion of the water vapour in the sample breaks through the concentrator during sampling to a degree depending on the multisorbent composition, duration of sampling, and other factors. Dry purging the concentrator with helium while retaining target compounds can further reduce water content of the sample. After the concentration and drying steps are completed, the VOCs are thermally desorbed, entrained in a carrier gas stream, and then focused in a small volume by trapping on a reduced temperature trap or a small volume multisorbent trap. The sample is then released by thermal desorption and carried onto a gas chromatographic column for separation.

The analytical strategy for US EPA Compendium Method TO-15A involves using a high-resolution gas chromatograph (GC) coupled to a mass spectrometer (MS). If the MS is a linear quadrupole system, it is operated either by continuously scanning a wide range of mass to charge ratios (SCAN mode) or by monitoring select ion monitoring mode (SIM) of compounds on the target list. If the MS is based on a standard ion trap design, only a scanning mode is used. Mass spectra for individual peaks in the total ion chromatogram are examined with respect to fragmentation pattern of ions corresponding to various VOCs including the intensity of primary and secondary ions. The fragmentation pattern is compared with stored spectra taken under similar conditions, in order to identify the compound.

For any given compound, the intensity of the primary fragment is compared with the system response to the primary fragment for known amounts of the compound. This establishes the compound concentration that exists in the sample. This method applies to ambient concentrations of VOCs above 0.5 ppbv and typically requires VOC enrichment by concentrating up to 1 L of a sample volume. The VOC concentration range for ambient air in many cases includes the concentration at which continuous exposure over a lifetime is estimated to constitute a 10^{-6} or higher lifetime risk of developing cancer in humans.

5.1.3 NIOSH Method 1501

In addition to the air monitoring methods for cumene developed by the US EPA, both the NIOSH and the OSHA have also developed methods for cumene that are suitable for occupational, personal and area monitoring. The methodology used by the NIOSH to determine cumene in air (NIOSH Method 1501) consists of collecting cumene on charcoal solid sorbent tubes with subsequent chemical analysis by gas chromatography with flame ionization detection (GC/FID) (NIOSH, 1994). The advantages of this method include: the sampling device is small, portable and involves no liquids; the analysis is by a quick instrumental method; interferences can be eliminated by altering chromatographic conditions in most cases; and the method allows for simultaneous analysis of two or more analytes. The disadvantages of this method include: the air volume sampled is limited by the capacity of the charcoal tubes; the method is limited by the reproducibility of the pressure drop across the tubes; the analyst must work with toxic solvents; and when many components are present, elimination of interferences becomes difficult. Sampling is conducted by drawing air through a solid sorbent tube (coconut shell charcoal, 100 mg in the front section and 50 mg in the back section) using a personal sampling pump. The suggested flow rate is less than 0.2 L/min and the minimum volume collected is 1 L and the maximum 30 L. The contents of the tube are desorbed with carbon disulphide and the desorbate is analyzed by GC/FID. The level of detection for concentrations of cumene using this method is 1.0 mg/m^3 (0.2 ppmv).

5.1.4 OSHA Method 7

OSHA has developed a fully validated method for the determination of cumene that is suitable for occupational, personal and area monitoring. The current methodology used by the OSHA to determine cumene in air (OSHA Method 7) was developed to be a more generalized version of validated NIOSH methodology (OSHA, 2000). This method consists of collecting cumene by drawing a known volume of air through standard sized sampling tubes (containing coconut shell charcoal, 100 mg in the front section and 50 mg in the back section) using a personal sampling pump. The suggested flow rate when sampling for cumene is 0.2 L/min and the recommended volume collected is 10 L after a sampling time of 50 minutes. Samples are desorbed with an organic solvent (carbon disulphide is commonly used as the desorption solution, although certain analytes can be more effectively desorbed with the use of alternate solvents or solvent solutions) and subsequently analyzed by GC/FID. The advantages of this method include: the sampling device is small, portable and involves no liquids; the analysis is by a quick instrumental method; interferences can be eliminated by altering chromatographic conditions in most cases; and the method allows for simultaneous analysis of two or more analytes. The disadvantages of this method include: the air volume sampled is limited by the capacity of the charcoal tubes; the method is limited by the reproducibility of the pressure drop across the tubes; the analyst must work with toxic solvents; and when many components are present, elimination of interferences becomes difficult. The detection limit of the overall procedure is 0.2 ppmv or 1.0 mg/m^3 for a 10 L air sample.

5.2 Alternative, Emerging Technologies

Reports, journal articles, conference proceedings, and other sources known to contain information on ambient measurement methods for chemicals such as cumene were reviewed to determine the current status of alternative and emerging technologies. The results of the review indicate a general lack of technologies for ambient monitoring of cumene beyond the reference methods described earlier. A recent US EPA sponsored survey reinforces this by pointing out the need for methods development for chemicals such as cumene (Mukund *et al.* 1995). Despite this need, several examples of alternative and emerging technologies have been developed and reported. In general, most non-standard methods and technologies are variations or modifications of those referenced methods previously mentioned. However, a few unique methods and technologies have been described, including passive and near-real time sampling methods. Refer to Table 8 for a description of individual method advantages and disadvantages.

A modified sampling and analytical technique similar to the standard methods has been recommended (Batterman *et al.* 2002; Peng and Batterman, 2000). In this method, sampling is conducted by drawing air through a sorbent tube containing a duel sorbent system (Tenax GR and Carbosieve). This method allows for the collection of ambient air at various flow rates including active flow (>10 mL/min), low flow (<10 mL/min) or passive flow (diffusion flow). Regardless of the flow rate used, a novel short path thermal desorption procedure is used to desorb the contents of the tube and the desorbate is subsequently analyzed by gas chromatography with mass spectrometry (GC/MS). The level of detection for concentrations of cumene using this method is approximately 0.010 $\mu g/m^3$ (0.002 ppbv).

A number of passive gas badge samplers have been developed to measure concentrations of cumene in air as an alternative to the standard active pump sampling techniques. The advantages of these samplers are that there are no moving parts to break down, regular flow calibration is unnecessary, and no bulky, expensive pumps are required. The badge is exposed to ambient conditions for a set period of time (usually a much longer period than for active pump sampling) and then analyzed by an appropriate analytical method (Brown and Wright, 1994; Levin and Lindahl, 1994). SKC Inc. (2004) has developed two such gas badge samplers for cumene that are suitable for the collection and analysis of low ppbv concentration levels. Cumene is absorbed by either charcoal (badge 1) or Anasorb 747 (badge 2) and subsequently detected by GC/FID. The level of detection for cumene using these gas badges has not been reported.

A novel prototype portable gas chromatograph suitable for routine, near-real time, quantitative determinations of ambient levels of specific VOCs (including cumene) has recently been described (Sanchez and Sacks, 2003; Lu *et al.* 2003). The key analytical features of the instrument include a miniature multiadsorbent preconcentrator/focuser (PCF); a tandem-column, high speed separation module with tunable retention capabilities; and a detector comprising an array of polymer-coated surface acoustic wave (SAW) microsensors that provides a characteristic fingerprint of each analyte. The determination of complex mixtures of ambient air contaminants in less than 10 minutes is possible. Detection limits of less than 10 ppbv are achieved for the majority of target analytes (including cumene) using a 1 L air sample.

Table 8 Method Advantages and Disadvantages

Method	Advantages	Disadvantages
US EPA TO-1	Good database Large volume of air can be sampled Water vapour is not collected Wide variety of compounds collected Low detection limits (i.e., 0.01-100 ppbv) Standard procedures available Practical for field use	Highly volatile compounds and certain polar compounds are not collected Rigorous clean-up of absorbent required No possibility of multiple analysis Low breakthrough volumes for some compounds Structural isomers are the most common interferences Contamination of absorbent and blank contaminants may be a problem Artifact formation
US EPA TO-15A	Addresses a large set of compounds Establishes method performance criteria for acceptance of data Provides quality control provisions Allows analysis for polar VOCs	Requires expensive analytical equipment Requires high level of operator skill
NIOSH Method 1501	Sampling device is small, portable and involves no liquids Analysis is by a quick instrumental method Interferences can be eliminated by altering chromatographic conditions in most cases Method allows for simultaneous analysis of two or more analytes	Air volume sampled is limited by the capacity of the charcoal tubes Method is limited by the reproducibility of the pressure drop across the tubes Analyst must work with toxic solvents When many components are present, elimination of interferences becomes difficult
OSHA Method 7	Sampling device is small, portable and involves no liquids Analysis is by a quick instrumental method Interferences can be eliminated by altering chromatographic conditions in most cases Method allows for simultaneous analysis of two or more analytes	Air volume sampled is limited by the capacity of the charcoal tubes Method is limited by the reproducibility of the pressure drop across the tubes Analyst must work with toxic solvents When many components are present, elimination of interferences becomes difficult
Alternative Sampling and Analytical Techniques	High resolution and low detection limits Can handle high humidity environments Minimizes artifacts, losses and carry-over effects	Temperature fluctuations may affect results Can be time consuming
Passive Samplers	No moving parts to break down Regular flow calibration unnecessary No bulky, expensive pumps required As reliable as conventional methods	Only reliable at higher ambient concentrations Long exposure times required
Near-Real Time Samplers	Reliable at low concentrations Fast response times Accurate	Bulky and expensive Complicated operation Many are insufficiently sensitive or selective

6.0 AMBIENT GUIDELINES OR OBJECTIVES

Current and/or recommended and proposed ambient guidelines and objectives of other jurisdictions in Canada, the United States, and elsewhere were reviewed for cumene. All jurisdictions have specific uses for their guidelines. These uses may include:

- Reviewing permit applications for sources that emit air pollutants to the atmosphere;
- Investigating accidental releases or community complaints about adverse air quality for the purpose of determining follow-up or enforcement activity, and;
- Determining whether to implement temporary emission control actions under persistent adverse air quality conditions of a short-term nature.

6.1 Cumene Air Quality Guidelines

The air quality guidelines and objectives available for cumene are summarized in Table 9. Further details on the development and use of these guidelines or objectives by each jurisdiction are provided in Appendix A. Principal approaches by which guidelines are developed involve using an occupational exposure level (OEL) or results from animal bioassay data and dividing it by safety or adjustment factors. Three types of OELs used by state agencies are: i) the American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour time weighted average occupational exposure limit (OEL) of 246 mg/m^3 (ACGIH, 2003); ii) the National Institute for Occupational Safety and Health (NIOSH) relative exposure level (REL) of 246 mg/m^3 (NIOSH, 2003); and iii) the US Occupational Safety and Health Administration (OSHA) 8-hour Permissible Exposure Limit (PEL) of 245 mg/m^3 (OSHA, 2003). Two other approaches by which guidelines are developed by state agencies involve using animal bioassay data and odor threshold information.

The safety or adjustment factors are intended to account for issues such as: differences between eight-hour exposures in the workplace and continuous 24-hour environmental exposures, increased susceptibility of some people in the general population versus the relatively healthy worker, and uncertainty in the margin of safety provided in an occupational exposure limit.

6.1.1 Canada

The Ontario Ministry of the Environment (MOE, 1999; 2001) adopted an Ambient Air Quality Criterion (AAQC) of 400 µg/m^3 as a 24-hour guideline based on the US EPA Reference Concentration. Ontario MOE uses a value of 400 µg/m^3 for a 30-minute maximum point of impingement (POI) guideline based on odor.

6.1.2 United States

The US EPA developed a chronic inhalation Reference Concentration (RfC) of 400 µg/m^3 (81 ppb) applicable to continuous exposure duration (US EPA, 2003). The RfC is based on a 13-week (sub-chronic) inhalation exposure study using rats. The RfC is intended for use by US EPA staff in risk assessments, decision-making and regulatory activities.

Three states – New Hampshire, Washington, and Wisconsin – use the American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour time weighted average occupational exposure limit (OEL) of 246 mg/m^3 for development of their 24-hour guidelines. Louisiana and Oklahoma use the National Institute for Occupational Safety and Health (NIOSH) relative exposure level (REL) of 246 mg/m^3 for development of their guidelines with corresponding averaging times ranging from 8 to 24 hours. Indiana and Vermont use the US Occupational Safety and Health Administration (OSHA) 8-hour Permissible Exposure Limit (PEL) of 245 mg/m^3 for development of their guidelines with corresponding averaging times ranging from 8 hours to annually.

Two states – Michigan and New Hampshire – use the US EPA Reference Concentration of 400 µg/m^3 for development of their guidelines, with corresponding averaging times ranging from 24 hours to annually. Texas uses unspecified odor threshold information for development of guidelines for a 1-hour and annual averaging time.

6.1.3 International Agencies

The New Zealand Ministry of Environment and Ministry of Health, the Netherlands National Institute of Public Health (RIVM, 2001), and WHO (2000) do not have air quality criteria for cumene.

Table 9 Summary of Air Quality Guidelines for Cumene

Agency	Guideline Title	Guideline Value [µg/m^3] Averaging Time:			
		1-hour	8-hour	24-hour	Annual
Ontario MOE (1999; 2001)	Ambient air quality criterion (AAQC):			400	
	Maximum point of impingement (POI) Guideline :	100 (30-min)			
US ATSDR (2003)	No guideline exists.				
US EPA (2003)	Reference Concentration (RfC):				400
Arizona DEQ (1999)	No guideline exists.				
California EPA (1992; 1999; 2003)	No guideline exists.				
Indiana DEM (2002)	Informal IDEM Limit:		1,225		
Louisiana DEQ (current)	Ambient air standard (AAS):		5,860		
Massachusetts DEP (1995)	No guideline exists.				
Michigan DEQ (current)	Initial threshold screening level (ITSL):			400	
New Hampshire DES (current)	Ambient air limit (AAL):			1,237	400
New Jersey DEP (current)	No guideline exists.				
North Carolina ENR (current)	No guideline exists.				
Ohio EPA (1994; 2003)	No guideline exists.				
Oklahoma DEQ (2002)	Maximum acceptable ambient concentration (MAAC):			24,582	
Rhode Island DEM (1992)	No guideline exists.				
Texas CEQ (2003)	Effects screening level (ESL):	500			50
Vermont ANR (2001)	Hazardous ambient air standard (HAAS):				583
Washington DOE (current)	Acceptable source impact level (ASIL):			820	
Wisconsin DNR (current)	Acceptable ambient concentration (AAC):			5,899	
New Zealand MOE (2000)	No guideline exists.				
The Netherlands (RIVM) (2000)	No guideline exists.				
World Health Organization (2000)	No guideline exists.				

7.0 DISCUSSION

Establishing an ambient air quality guideline in the form of a concentration limit with a corresponding exposure duration (*i.e.*, averaging time) requires a number of factors to be taken into account, including:

- The nature of adverse health effects and conditions of exposure (*e.g.*, concentration and duration) associated with these effects;
- The estimated or actual degree of exposure of receptors, in particular those that may be sensitive to the air pollutant;
- The available technologies and associated economics for routinely or periodically monitoring for the pollutant in air, and;
- The availability and suitability of approaches for screening and estimating ambient ground-level concentrations in order to compare to the guidelines for permit applications or other situations.

Cumene is a reportable substance for Environment Canada's NPRI. Canadian industrial sectors contributing to cumene emissions include the crude petroleum and natural gas industries, refined petroleum and coal products industries, the chemical and chemical products industries and the plastic products industries (NPRI, 2004). In urban air samples, mean ambient concentrations of cumene ranged from 0.245 to 16.7 $\mu g/m^3$ (HSDB, 2004).

Standard air monitoring methods for cumene are based on solid sorbent, canister or pump-and-tube sampling approaches that are followed with various analytical techniques. Widely employed and accepted reference air monitoring methods for cumene have been developed, tested, and reported by the US EPA, NIOSH, and OSHA. There are currently no standard air sampling and analytical methods for cumene employed in either Alberta or Canada.

Ambient air guidelines in the form of short-term (acute) and long-term (chronic) duration are discussed below for cumene. Ideally, air quality guidelines serve to address exposures related to humans, animals, and vegetation. No direct exposure-related information was obtained for humans or terrestrial vegetation; therefore the discussion emphasizes the effects of cumene in experimental animals.

7.1 Acute Exposure Conditions

Acute inhalation exposure of rats to high concentrations of cumene vapour (from 2,430 mg/m^3 over a 6 hour period to 39,200 mg/m^3 over a 20 minute period) resulted in various acute neurobehavioural effects. In all cases, symptoms subsided following withdrawal from exposure; recovery was quicker in animals exposed to lower air concentrations of cumene or exposed for short time periods (*i.e.*, 20 minutes).

Acute neurobehavioural effects were reported in rats sub-acutely exposed to cumene vapour concentrations of 9,800 mg cumene/m^3 (6 hours/day, 5 days), 2,680 to 6,321 mg cumene/m^3 (6 hours a day, 5 days/week, 2 weeks), and from 515 to 2,935 mg cumene/m^3 (6 hours/day, 5 days/week, 4 weeks).

Two separate studies reported the same NOAEL of 490 µg/m^3 for acute neurobehavioural effects in rats exposed to cumene vapours for a single 6 hour period. This was the lowest NOAEL identified from acute or sub-acute exposure studies. The lowest LOAEL identified was 515 µg/m^3, reported for neurobehavioural effects in rats exposed to cumene vapours for 6 hours a day, 5 days a week over a 4 week period.

Provincial and state agencies that have developed acute air quality guidelines for cumene (averaging times of 24-hours or less) include Ontario MOE, Indiana DEM, Louisiana DEQ, Michigan DEQ, New Hampshire DES, Oklahoma DEQ, Texas CEQ, Washington DOE, and Wisconsin DNR.

The Ontario 24-hour TWA guideline and 30-minute maximum POI for cumene is 400 µg/m^3 and is based on odor. Texas also used unspecified odor threshold information for development of a short-term (1-hour) effects screening level of 500 µg/m^3.

New Hampshire, Washington, and Wisconsin based their 24-hour guidelines on the ACGIH 8-hour TWA OEL of 246 mg/m^3. The New Hampshire 24-hour ambient air limit of 1,237 µg/m^3 is based on the ACGIH OEL divided by a safety factor of 71 and a time adjustment factor of 2.8. The Washington 24-hour acceptable source impact level of 820 µg/m^3 is equivalent to the ACGIH OEL divided by a safety factor of 300 and rounded. Wisconsin developed a 24-hour acceptable ambient concentration of 5,899 µg. This represents two and four tenths percent of the ACGIH OEL.

Louisiana and Oklahoma use the 8-hour NIOSH REL of 246 mg/m^3 for development of guidelines with averaging times ranging from 8 to 24 hours. The Louisiana ambient air standard for cumene is 5,860 µg/m^3; equivalent to the NIOSH REL divided by a factor of 42 and rounded a common adjustment to convert from occupational to continuous exposure. The Oklahoma maximum acceptable ambient concentration of 24,582 µg/m^3, averaged over 24-hours, is based on the NIOSH REL divided by a factor of 10.

The 8-hour guideline recommended by Indiana is based on the US OSHA 8-hour PEL of 245 mg/m^3. The Indiana DEM value of 1,225 µg/m^3 represents 0.5% of the OSHA PEL.

The Michigan initial threshold screening level and the Ontario ambient air quality criterion (both 400 µg/m^3 averaged over 24-hours) are equal to the US EPA Reference Concentration recommended for cumene.

7.2 Chronic Exposure Conditions

Depending on the agency involved, the NOAEL reported for cumene in sub-chronic (13 week) inhalation studies ranged from 490 mg/m^3 (WHO, ECB) to 2,430 mg/m^3 (US EPA) for effects observed in the adrenals and kidneys of rats. The corresponding LOAELs for these effects were 2,430 mg/m^3 and 5,890 mg/m^3, respectively.

A NOAEL of 5,890 mg/m^3 was reported for cumene effects on respiratory tract tissue, lung weights, and reproductive parameters. No adverse effects were reported following continuous exposure of rats, guinea pigs, dogs and monkeys for 90 days to cumene vapours of 18, or 147 mg/m^3.

A LOAEL of 2,391 mg/m^3 and a NOAEL of 485 mg/m^3 were reported for maternal effects in female rats exposed to cumene vapours during gestation. The developmental NOAEL for this study was 5,934 mg/m^3. In female rabbits, a NOAEL of 5,909 mg/m^3 was reported for maternal and developmental effects following exposure to cumene vapours during gestation.

Agencies that have developed chronic air quality guidelines (annual average) for cumene include the US EPA, New Hampshire DES, Texas CEQ, and Vermont ANR.

The US EPA developed a chronic inhalation Reference Concentration (RfC) of 400 µg/m^3 based on a sub-chronic NOAEL of 2,430 mg/m^3 for effects observed in the adrenals and kidneys of rats following 13-weeks inhalation exposure. The New Hampshire annual ambient air limit of 400 µg/m^3 is equal to the US EPA Reference Concentration. The Texas long-term effects (annual average) screening level of 50 µg/m^3 (10 ppb) is based on unspecified odor threshold information. The Vermont hazardous ambient air standard of 583 µg/m^3 is equal to the OSHA 8-hour PEL (245 mg/m^3) divided by a factor of 420 and rounded to convert from occupational to continuous exposures.

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APPENDIX A
Air Quality Objectives for Cumene Development and Use

Agency: Ontario Ministry of the Environment (OME).
Air Quality Guideline: Ambient Air Quality Criterion (AAQC) = 400 µg/m^3.
Averaging Time To Which Guideline Applies: 24-hour averaging time.
Basis for Development: OME adopted the US Environmental Protection Agency Reference Concentration (RfC) listed in this report as a health-based 24-hour criterion.
Date Guideline Developed: March 2001.
How Guideline is Used in Practice: Used by Ontario Ministry of Environment (OME) to represent human health or environmental effect-based values not expected to cause adverse effects based on continuous exposure.
Additional Comments: AAQC is not used by OME to permit stationary sources that emit cumene to the atmosphere. A "point of impingement" standard is used to for permitting situations.
Reference and Supporting Documentation: Ontario Ministry of the Environment. 2001. Ontario Air Standards for Isopropyl Benzene. Standards Development Branch, Ontario Ministry of the Environment, Toronto, ON. March 2001. 55 pp.

Agency: Ontario Ministry of the Environment (OME).
Air Quality Guideline: Maximum point of impingement (POI) Standard = 100 $\mu g/m^3$.
Averaging Time To Which Guideline Applies: 30-minute averaging time.
Basis for Development: OME maintained their current odor-based 30-minute POI standard adopted prior to March 2001.
Date Guideline Developed: March 2001.
How Guideline is Used in Practice: Used by OME to review permit applications for stationary sources that emit cumene to the atmosphere.
Additional Comments: n/a
Reference and Supporting Documentation: Ontario Ministry of the Environment. 2001. Ontario Air Standards for Isopropyl Benzene. Standards Development Branch, Ontario Ministry of the Environment, Toronto, ON. March 2001. 55 pp.

Agency: US Agency for Toxic Substances and Disease Registry (ATSDR).
Air Quality Guideline: ATSDR does not have an air quality guideline for this chemical.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: Agency for Toxic Substances and Disease Registry (ATSDR). 2003. Minimal Risk Levels (MRLs) for Hazardous Substances. ATSDR, Public Health Service, US Department of Health and Human Services. Atlanta, GA. Available at: http://www.atsdr.cdc.gov/mrls.html (accessed 6 November 2003).

Agency: US Environmental Protection Agency (EPA).
Air Quality Guideline: Reference Concentration (RfC) = 400 $\mu g/m^3$ (81 ppb).
Averaging Time To Which Guideline Applies: Continuous exposure (daily exposure over a lifetime).
Basis for Development: The RfC was developed as follows. A 13-week inhalation exposure study to rats identified a no-observed-adverse-effects-level (NOAEL) of 2,438 mg/m^3 (496 ppm) based on absence of increased kidney weights in female rats and adrenal weights in male and female rats. A human equivalent concentration (HEC) of 435 mg/m^3 was adjusted with an uncertainty factor of 1000 to derive a RfC of 400 $\mu g/m^3$ (81 ppb) after rounding.
Date Guideline Developed: August 1997.
How Guideline is Used in Practice: The reference concentration (RfC) is intended for use by US EPA staff in risk assessments, decision-making and regulatory activities.
Additional Comments: The Integrated Risk Information System (IRIS) is prepared and maintained by the US EPA. IRIS is an electronic database containing information on human health effects that may result from exposure to various chemicals in the environment.
Reference and Supporting Documentation: US Environmental Protection Agency. Integrated Risk Information System. Available at: http://www.epa.gov/iris/ (accessed 6 November 2003).

Agency: Arizona Department of Health Services (DHS).
Air Quality Guideline: Arizona DHS does not have an air quality guideline for this chemical.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: Arizona Department of Health Services (DHS). 1999. 1999 Update – Arizona Ambient Air Quality Guidelines (AAAQGs). Report prepared for Arizona Department of Environmental Quality, Air Programs Division. Arizona DHS, Office of Environmental Health, Phoenix, AZ. 11 May 1999. 20 pp.

Agency: California Environmental Protection Agency (Cal EPA).
Air Quality Guideline: Cal EPA does not have an air quality guideline for this chemical.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: California Environmental Protection Agency (Cal EPA). 1999. Determination of Acute Reference Exposure Levels for Airborne Toxicants. Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, Cal EPA. Oakland, CA. March 1999. California Air Pollution Control Officers Association (CAPCOA). 1992. Air Toxics "Hot Spots" Program Risk Assessment Guidelines, Prepared by AB2588 Risk Assessment Committee of CAPCOA, Sacramento, CA. January 1992. California Office of Environmental Health Hazard Assessment (OEHHA)/Air Resources Board (ARB). 2003. Approved Chronic Reference Exposure Levels and Target Organs. Table 3 (last updated 4 December 2003). Available at: www.arb.ca.gov/toxics/healthval/chronic.pdf (accessed 5 December 2003).

Agency: Indiana Department of Environmental Management (IDEM).
Air Quality Guideline: Informal IDEM limit = 1,225 $\mu g/m^3$ (249 ppb).
Averaging Time To Which Guideline Applies: 8-hour averaging time.
Basis for Development: For hazardous air pollutants, including cumene, IDEM developed an informal limit from US Occupational Safety and Health Administration (OSHA) 8-hour Permissible Exposure Limits (PELs), found in 29 CFR Part 1910.1000, Air Contaminants Rule. The 8-hour PEL for cumene is 245 mg/m^3. Concentrations that are a small percentage (0.5%) of the PEL are used by IDEM to indicate that there should not be significant impacts on public health and welfare. This is equivalent to 1,225 $\mu g/m^3$ (249 ppb) for cumene.
Date Guideline Developed: Unknown.
How Guideline is Used in Practice: Informal limits are used by IDEM to review results from air dispersion modeling and other issues related to permit applications for sources that emit cumene to the atmosphere. Sources are regulated through an air permitting system and include any new, modified or existing stationary sources. IDEM uses 0.5% of the OSHA PEL as an informal limit (threshold) for triggering further discussion with the source and possible additional air dispersion modeling.
Additional Comments: OSHA sets PELs to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air in the workplace. OSHA PELs are based on an 8-hour time weighted average (TWA) exposure.
Reference and Supporting Documentation: Indiana Department of Environmental Management (DEM). 2002. Office of Air Quality Programs. Indiana DEM, Office of Air Quality. Indianapolis, IN. Available at: http://www.in.gov/idem/air/programs/modeling/policy.html (accessed 5 December 2003). US Occupational Safety and Health Administration (OSHA). 2003. TABLE Z-1 Limits for Air Contaminants. - 1910.1000 TABLE Z-1. US Department of Labor, OSHA, Washington, DC. Available at: www.osha-slc.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992 (accessed 5 December 2003).

Agency: Louisiana Department of Environmental Quality (DEQ).
Air Quality Guideline: Ambient air standard (AAS) for toxic air pollutants = 5,860 µg/m^3 (1,192 ppb).
Averaging Time To Which Guideline Applies: 8-hour averaging time.
Basis for Development: Unknown. The AAS is equivalent to the National Institute for Occupational Safety and Health (NIOSH) relative exposure level (REL) of 246 mg/m^3 divided by a factor of 42 and rounded. The factor of 42 is a common adjustment representing a safety factor of 10 and 8/24 and 5/7 multipliers to convert 8-hour per 24-hour day and 5-day per 7-day week occupational exposures to continuous exposures.
Date Guideline Developed: Unknown.
How Guideline is Used in Practice: AASs are used by Louisiana DEQ to review permit applications for stationary sources that emit cumene to the atmosphere.
Additional Comments: n/a
Reference and Supporting Documentation: *Louisiana Administrative Code (LAC). Title 33 Environmental Quality, Part III Air, Chapter 51. Comprehensive Toxic Air Pollutant Emission Control Program. Louisiana Department of Environmental Quality. Baton Rouge, LA.* National Institute for Occupational Safety and Health (NIOSH). 2003. NIOSH Pocket Guide to Chemical Hazards (NPG) Online. NIOSH, Department of Health and Human Services, Centers for Disease Control and Prevention, Atlanta, GA. Available at: http://www.cdc.gov/niosh/npg/npg.html (accessed 5 December 2003).

Agency: Massachusetts Department of Environmental Protection (DEP).
Air Quality Guideline: Massachusetts DEP does not have an air quality guideline for this chemical.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: Massachusetts Department of Environmental Protection (DEP). 1995. Revised air guidelines [updated list of 24-hour average Threshold Effects Exposure Limit (TEL) values and annual average Allowable Ambient Limit (AAL) values]. Massachusetts DEP, Boston, MA. 6 December 1995. Memorandum. Available at: http://www.state.ma.us/dep/ors/files/aallist.pdf (accessed 5 December 2003).

Agency: Michigan Department of Environmental Quality (DEQ).
Air Quality Guideline: Initial threshold screening level (ITSL) = 400 $\mu g/m^3$ (81 ppb).
Averaging Time To Which Guideline Applies: 24-hour averaging time.
Basis for Development: Based on the US Environmental Protection Agency Reference Concentration (RfC) listed in this report.
Date Guideline Developed: 1997.
How Guideline is Used in Practice: There are two basic requirements of Michigan air toxic rules. First, each source must apply the best available control technology for toxics (T-BACT). After the application of T-BACT, the emissions of the toxic air contaminant cannot result in a maximum ambient concentration that exceeds the applicable health based screening level for non-carcinogenic effects (ITSL). Application of an ITSL is required for any new or modified emission source or sources for which a permit to install is requested and which emits a toxic air contaminant.
Additional Comments: The applicable air quality screening level for chemical treated as non-carcinogens by Michigan DEQ is the ITSL. There are two health based screening levels for chemical treated as carcinogens by Michigan DEQ: the initial risk screening level (IRSL) – based on an increased cancer risk of one in one million, and the secondary risk screening level (SRSL) – based on as an increased cancer risk of 1 in 100,000.
Reference and Supporting Documentation: *Michigan Administrative Code (MAC). Air Pollution Control Rules. Part 2 Air Use Approval, R 336.1201 - 336.1299. Air Quality Division, Department of Environmental Quality. Lansing, MI.*

Agency: New Hampshire Department of Environmental Services (DES).
Air Quality Guideline: 24-hour ambient air limit (AAL) = 1,237 µg/m^3 (252 ppb). Annual ambient air limit (AAL) = 400 µg/m^3 (81 ppb).
Averaging Time To Which Guideline Applies: See above.
Basis for Development: The AALs were developed in the following manner: 24-hour Ambient Air Limit – The American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour time weighted average occupational exposure limit (OEL) of 246 mg/m^3 (50 ppm) is divided by a safety factor (SF) of 71 and a time adjustment factor (TAF) of 2.8. Annual Ambient Air Limit – Based on the US Environmental Protection Agency Reference Concentration (RfC) listed in this report.
Date Guideline Developed: Unknown.
How Guideline is Used in Practice: AALs are used by New Hampshire DES to review permit applications for sources that emit cumene to the atmosphere. Sources are regulated through a statewide air permitting system and include any new, modified or existing stationary source, area source or device.
Additional Comments: n/a
Reference and Supporting Documentation: *New Hampshire Administrative Rule. Chapter Env-A 1400. Regulated Toxic Air Pollutants. New Hampshire Department of Environmental Services. Concord, NH.* American Conference of Governmental Industrial Hygienists (ACGIH). 2003. 2003 TLVs and BEIs. Publication #0103. ISBN: 1-882417-49-6. ACGIH, Cincinnati, OH. 224 pp.

Agency: New Jersey Department of Environmental Protection (DEP).
Air Quality Guideline: Applicants are required to carry out a risk assessment in conjunction with applying for an air pollution control pre-construction permit. New Jersey DEP normally uses US EPA toxicological criteria from the Integrated Risk Information System. In the case of cumene, US EPA has a Reference Concentration (RfC) of 400 $\mu g/m^3$ listed in this report.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: *New Jersey Administrative Code (NJAC). Title 7, Chapter 27, Subchapter 8. Permits and Certificates for Minor Facilities (and Major Facilities without an Operating Permit). New Jersey Department of Environmental Protection. Trenton, NJ.* New Jersey Department of Environmental Protection. 1994. Technical Manual 1003. Guidance on Preparing a Risk Assessment for Air Contaminant Emissions. Air Quality Permitting Program, Bureau of Air Quality Evaluation, New Jersey Department of Environmental Protection. Trenton, NJ. Revised December 1994.

Agency: North Carolina Department of Environment and Natural Resources (ENR).
Air Quality Guideline: North Carolina ENR does not have an air quality guideline for cumene.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: *North Carolina Administrative Code (NCAC). North Carolina Air Quality Rules 15A NCAC 2D.1100 – Air Pollution Control Requirements (Control of Toxic Air Pollutants). North Carolina Department of Environment and Natural Resources. Raleigh, NC.* *North Carolina Administrative Code (NCAC). North Carolina Air Quality Rules 15A NCAC 2Q.0700 – Air Quality Permit Procedures (Toxic Air Pollutant Procedures). North Carolina Department of Environment and Natural Resources. Raleigh, NC.*

Agency: Ohio Environmental Protection Agency (EPA).
Air Quality Guideline: Ohio EPA does not have an air quality guideline for cumene.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: Ohio Environmental Protection Agency (EPA). 2003. Review of New Sources of Toxic Emissions. Air Toxics Unit, Division of Air Pollution Control, Ohio EPA. Columbus, OH. 11 pp. Available at: http://www.epa.state.oh.us/dapc/atu/atu.html (accessed 5 December 2003). Ohio Environmental Protection Agency (Ohio EPA). 1994. Review of New Sources of Air Toxic Emissions. Proposed for Public Comment. Division of Air Pollution Control, Ohio EPA. Columbus, OH. January 1994. 31 pp.

Agency: Oklahoma Department of Environmental Quality (DEQ).
Air Quality Guideline: Maximum acceptable ambient concentration (MAAC) = 24,582 $\mu g/m^3$ (5,000 ppb).
Averaging Time To Which Guideline Applies: 24-hour averaging time.
Basis for Development: The MAAC is the National Institute for Occupational Safety and Health (NIOSH) relative exposure level (REL) of 246 mg/m^3 divided by a factor of 10. In this case, the factor of 10 is applied to substances that are considered by Oklahoma DEQ to be of low toxicity.
Date Guideline Developed: Not stated.
How Guideline is Used in Practice: MAACs are used by Oklahoma DEQ to review permit applications for sources that emit cumene to the atmosphere.
Additional Comments: n/a
Reference and Supporting Documentation: *Oklahoma Administrative Code (OAC). Title 252. Chapter 100. Air Pollution Control. 100:252-41 - Control of Emission of Hazardous and Toxic Air Contaminants. Oklahoma Department of Environmental Quality. Oklahoma City, OK.* Oklahoma Department of Environmental Quality (DEQ). 2002. Air Toxics Partial Listing [maximum acceptable ambient concentrations (MAAC) for air toxics]. Oklahoma City, OK. Available at: http://www.deq.state.ok.us/AQDNew/toxics/listings/pollutant_query_1.html (accessed 5 December 2003). National Institute for Occupational Safety and Health (NIOSH). 2003. NIOSH Pocket Guide to Chemical Hazards (NPG) Online. NIOSH, Department of Health and Human Services, Centers for Disease Control and Prevention, Atlanta, GA. Available at: http://www.cdc.gov/niosh/npg/npg.html (accessed 5 December 2003).

Agency: Rhode Island Department of Environmental Management (DEM).
Air Quality Guideline: Rhode Island DEM does not have an air quality guideline for cumene.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: *Rhode Island Department of Environmental Management. 1992. Air Pollution Control Regulation No. 22. Division of Air and Hazardous Materials, Rhode Island Department of Environmental Management. Providence, RI. Amended 19 November 1992.*

Agency: Texas Commission on Environmental Quality (CEQ) – formerly Texas Natural Resource Conservation Commission (TRNCC).
Air Quality Guideline: Short-term effects screening level (ESL) = 500 $\mu g/m^3$ (100 ppb). Long-term effects screening level (ESL) = 50 $\mu g/m^3$ (10 ppb).
Averaging Time To Which Guideline Applies: 1-hour averaging time for short-term ESL. Annual averaging time for long-term ESL.
Basis for Development: Short-term Effects Screening Level – unknown other than it is based on odor. Long-term Effects Screening Level – unknown other than it is based on odor.
Date Guideline Developed: Not stated.
How Guideline is Used in Practice: ESLs are used to evaluate the potential for effects to occur as a result of exposure to concentrations of constituents in air. ESLs are based on data concerning health effects, odor nuisance potential, effects with respect to vegetation, and corrosion effects. They are not ambient air standards. If predicted or measured airborne levels of a chemical do not exceed the screening level, adverse health or welfare effects would not be expected to result. If ambient levels of constituents in air exceed the screening levels, it does not necessarily indicate a problem, but rather, triggers a more in-depth review.
Additional Comments: n/a
Reference and Supporting Documentation: Texas Natural Resource Conservation Commission (TNRCC) 2001. Toxicology & Risk Assessment (TARA) Section Effects Screening Levels. Available at: http://www.tnrcc.state.tx.us/permitting/tox/index.html (accessed 5 December 2003).

Agency: Vermont Agency of Natural Resources (ANR).
Air Quality Guideline: Hazardous ambient air standard (HAAS) = 583 µg/m^3 (119 ppb).
Averaging Time To Which Guideline Applies: Annual averaging time.
Basis for Development: Unknown. However the HAAS is equivalent to the US Occupational Safety and Health Administration (OSHA) 8-hour Permissible Exposure Limit (PEL) of 245 mg/m^3 divided by a factor of 420 and rounded. The factor of 420 is an adjustment representing a safety factor of 100 and 8/24 and 5/7 multipliers to convert 8-hour per 24-hour day and 5-day per 7-day week occupational exposures to continuous exposures.
Date Guideline Developed: Not stated.
How Guideline is Used in Practice: HAASs are used by Vermont ANR to review permit applications for stationary sources that emit cumene to the atmosphere.
Additional Comments: n/a
Reference and Supporting Documentation: Vermont Air Pollution Control Regulations. 2001. Appendix C - Rule 5-261 - Control of Hazardous Air Contaminants, Vermont Air Pollution Control Regulations. State of Vermont Agency of Natural Resources. Air Pollution Control Division. Waterbury, VT. 29 November 2001. 187 pp. US Occupational Safety and Health Administration (OSHA). 2003. TABLE Z-1 Limits for Air Contaminants. - 1910.1000 TABLE Z-1. US Department of Labor, OSHA, Washington, DC. Available at: www.osha-slc.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992 (accessed 5 December 2003).

Agency: Washington State Department of Ecology (DOE).
Air Quality Guideline: Acceptable source impact level (ASIL) = 820 $\mu g/m^3$ (167 ppb).
Averaging Time To Which Guideline Applies: 24-hour averaging time.
Basis for Development: The ASIL is equivalent to the American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour time weighted average occupational exposure limit (OEL) of 246 mg/m^3 divided by a safety factor (SF) of 300 and rounded.
Date Guideline Developed: Unknown.
How Guideline is Used in Practice: ASILs are used by Washington State DOE to review permit applications for sources that emit cumene to the atmosphere.
Additional Comments: n/a
Reference and Supporting Documentation: *Washington Administrative Code (WAC). Chapter 173-460 WAC. Controls For New Sources Of Toxic Air Pollutants. Washington State Department of Ecology. Olympia, WA.* American Conference of Governmental Industrial Hygienists (ACGIH). 2003. 2003 TLVs and BEIs. Publication #0103. ISBN: 1-882417-49-6. ACGIH, Cincinnati, OH. 224 pp.

Agency: Wisconsin Department of Natural Resources (DNR).
Air Quality Guideline: Acceptable ambient concentration (AAC) = 5,899 µg/m^3 (1,200 ppb).
Averaging Time To Which Guideline Applies: 24-hour averaging time.
Basis for Development: The AAC represents two and four tenths percent of the American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour time weighted average occupational exposure limit (OEL) of 246 mg/m^3.
Date Guideline Developed: Unknown.
How Guideline is Used in Practice: Used by Wisconsin DNR to review permit applications for stationary sources that emit cumene to the atmosphere.
Additional Comments: n/a
Reference and Supporting Documentation: *Wisconsin Administrative Code (WAC). Air Pollution Control Rules. Chapter NR 445. Control of Hazardous Pollutants. Wisconsin Department of Natural Resources. Madison WI.* American Conference of Governmental Industrial Hygienists (ACGIH). 2003. 2003 TLVs and BEIs. Publication #0103. ISBN: 1-882417-49-6. ACGIH, Cincinnati, OH. 224 pp.

Agency: New Zealand Ministry for the Environment (MOE) and New Zealand Ministry of Health (MOH).
Air Quality Guideline: New Zealand MOE and MOH do not have air quality criteria for cumene.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: New Zealand Ministry for the Environment and Ministry of Health (New Zealand). 2000. Proposals for Revised and New Ambient Air Quality Guidelines. Discussion Document. Air Quality Technical Report No 16. Prepared by the Ministry for the Environment and the Ministry of Health. December 2000. 79 pp.

Agency: The Netherlands National Institute of Public Health and the Environment (RIVM)
Air Quality Guideline: RIVM does not have air quality criteria for cumene.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: The Netherlands National Institute of Public Health and the Environment (RIVM). 2001. Re-evaluation of human-toxicological maximum permissible risk levels. RIVN Report 711701 025. RIVN, Bilthoven, The Netherlands. March 2001. 297 pp.

Agency: World Health Organization (WHO)
Air Quality Guideline: WHO does not have air quality criteria for cumene.
Averaging Time To Which Guideline Applies: n/a
Basis for Development: n/a
Date Guideline Developed: n/a
How Guideline is Used in Practice: n/a
Additional Comments: n/a
Reference and Supporting Documentation: World Health Organization (WHO). 2000. Air Quality Guidelines for Europe, 2nd Edition. WHO Regional Publications, European Series, No. 91. WHO Regional Office for Europe, Copenhagen. 273 pp.